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New records of bees (Hymenoptera, Apoidea) from Morocco

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Abstract
Morocco is considered to be one of the main diversity hotspots of bees in the Mediterranean basin. However, this fauna remains largely understudied in both urban and natural eco-systems. Bee monitoring primarily conducted during 2023 in an urban area (i.e. Safi) has unveiled three new bee species for Morocco: *Lithurgus tibialis*, *Tetralonia* aff. *lanzarotensis* and *Coelioxys ruficauda* as well as records of 28 new bee species for the region Marrakech Safi. This work provides descriptions of the spatial distribution, the diagnostic characters, and host plants of these three species. We also take the opportunity to highlight the quality of urban areas as habitats for bees and the importance of implementating bee-friendly management practices to preserve bee species.

Keywords
Bee conservation, cemetery, city, management practices, Mediterranean, new species

Introduction

Morocco has a unique geographical position, situated at a crossroads of two biogeographical regions (i.e. the Afrotropic and the Palaearctic). This country is characterized by a wide topographic gradient, from the Atlantic and Mediterranean coasts to the

summit of the Atlas Mountains, and different climate types, from Mediterranean in the north to arid desert in the south, leading to a wide range of habitats (e.g. sclerophyllous forest, alpine meadows, coastal cliffs, shrubs, semideserts). From this habitat diversity derives the diverse Moroccan flora (Rankou et al. 2013), which in turn provides key ecosystem services.

The economic value of insect pollination in Morocco is up to $1.23 billion, representing 8.5% of the total value of agricultural gross domestic product (Sabbahi 2022) and 25% of the total value of agricultural production in North Africa (Gallai et al. 2009). The main non-bee pollinators recorded in the country are butterflies with 136 species (Verovnik et al. 2018) and hoverflies with 150 species (Sahib et al. 2020). In comparison, the Moroccan bee fauna impressively includes 962 bee species, which are classified in six bee families and 68 genera (Lhomme et al. 2020). This figure is comparable to that of other Mediterranean countries, such as Greece (1186), Spain (1166), and Italy (1051) (Reverté et al. 2023), collectively demonstrating the vast Mediterranean bee fauna (Orr et al. 2021).

Many bee species have already been recorded since the first check list of Lhomme et al. (2020), and other have been newly described (Wood et al. 2020, 2021; Wood 2023a, Wood 2023b) or await future description, and these will be ultimately added to the national list of Moroccan bees. The monitoring of Moroccan bees is spatially uneven, with a focus on agro-ecosystems (El Abdouni et al. 2022) and touristic areas (e.g. Michez et al. 2007). Further inventory studies are required to document the species diversity of Moroccan bees, especially in natural and urban areas.

As a first step to fill this gap, this work reports three species newly recorded for Morocco, which were discovered during faunal surveys in a coastal urban area in the middle of the country (city of Safi) and a botanical garden (Meknes). For each species, we provide information on spatial distribution, diagnosis, records of host plants and illustrations. Finaly, we highlight the importance of urban areas as a refuge for bees in a Mediterranean country.

Methods

Study area

All the bees were collected in Morocco at Safi (latitude: 32.2439 to 32.3418, longitude: -9.2069 to -9.2445), except two specimens, which were collected in Meknes (33.84079, -5.47737). Safi is a small city located on the Atlantic coast of western Morocco, while Meknes is situated in northern Morocco. Both towns are characterized by a Mediterranean climate with hot, dry summers and mild, wet winters. Bees were collected between February and October 2023 along roadsides, at cemeteries, and in vacant lots in Safi (Fig. 1), and in the botanical garden of the National School of Agriculture (ENAM) in Meknes, located 20 km south-east from the city.

Figure 1. Illustrations of the sites that were surveyed within Safi, Morocco **A** cemetery **B** roadside borders **C** vacant lots.

Bee identification

All bees were identified to the genus level following keys adapted from Michez et al. (2019), then sent to expert taxonomists for specific identification. Van der Zanden (1986), Al-Shahat and Hossni (2020), and available reference collections were used for morphological identification of the newly recorded species. The following abbreviations were used in the diagnosis: S = metasomal sterna and T = metasomal terga.

Bee pictures

The pictures of the new bee species were taken with an Olympus OMD E-M1 Mark II camera, using the Olympus Zuiko 60 mm objective and a Marumi lens for general habitus and a Mitutoyo plan achromatic lens LWD 5×. Images were stacked with the Helicon software and then enhanced with Adobe Photoshop CS6.

Pollen preparation and identification

Pollen host plants of the species newly recorded from Morocco were identified by examining pollen loads removed from female specimens under a microscope. *Coelioxys*, which is a parasitic (cuckoo) bee and *Lithurgus*, which comprised only males, were excluded from the pollen analysis, because they do not collect pollen. The pollen preparation followed the protocol described by Wood and Roberts (2017). Pollen load sizes were visually estimated relative to the bee size, ranging from a full load (1) to a

one-fourth load (0.25). Pollen grains were extracted from the scopa of females and deposited onto a microscope slide using an entomological pin. The pollen was then placed in a drop of water to separate aggregates. After gentle heating to allow evaporation, pollen grains were dried using a cube of fuchsin jelly added and melted to seal the slide with a coverslip. Pollen grains were finally identified to the subfamily level using author's personal experience and pollen picture databases (PalDat 2024).

Results

Bee species records

We collected a total of 1,624 bees, belonging to 27 genera and 102 identified bee species (Suppl. material 1). *Eucera* represented 27% of the total abundance, followed by *Andrena* (12%), *Tetralonia* (11%), *Osmia* (9%) and *Nomada* (9%) (Table 1). The most species-rich genera were *Andrena* (20 species), *Eucera* (10 species), *Osmia* (9 species) and *Anthophora* (8 species) (Table 1). Twenty eight percent of the species collected in Safi

Table 1. A summary of the list of genera collected in this study. The bee species richness (i.e., number of distinct bee species per genus) and abundance (i.e., the number of bee individuals collected per genus) are indicated.

Family	Genus	Bee species richness	Bee abundance
Andrenidae	*Andrena*	20	148
Apidae	*Eucera*	10	347
Apidae	*Anthophora*	8	64
Apidae	*Nomada*	7	109
Apidae	*Thyreus*	4	5
Apidae	*Amegilla*	3	23
Apidae	*Ammobates*	2	13
Apidae	*Ceratina*	2	9
Apidae	*Tetralonia*	2	136
Colletidae	*Colletes*	2	3
Colletidae	*Hylaeus*	1	12
Halictidae	*Lasioglossum*	5	19
Halictidae	*Halictus*	2	22
Halictidae	*Nomioides*	2	39
Halictidae	*Seladonia*	2	23
Halictidae	*Nomiapis*	1	3
Halictidae	*Rophites*	1	3
Halictidae	*Sphecodes*	1	9
Megachilidae	*Osmia*	9	119
Megachilidae	*Megachile*	7	61
Megachilidae	*Hoplitis*	4	32
Megachilidae	*Rhodanthidium*	2	15
Megachilidae	*Anthidium*	1	4
Megachilidae	*Chelostoma*	1	4
Megachilidae	*Coelioxys*	1	20
Megachilidae	*Lithurgus*	1	2
Megachilidae	*Stelis*	1	1

(i.e., 28 bee species) are new records for the region Marrakech Safi (Suppl. material 1) and *Tetralonia* aff. *lanzarotensis* and *Coelioxys ruficauda* are new species for the country. The two specimens collected in Meknes represent males of *Lithurgus tibialis*, marking its first recorded occurrence in Morocco.

New species for Morocco

Lithurgus tibialis Morawitz, 1875

Material examined. Morocco. 2♂; Meknes; 33.8405, -5.4775; 22 Jul. 2023; A. Sentil leg.; sweep net.

Diagnosis. The male of *Lithurgus tibialis* is distinguished from other Palaearctic *Lithurgus* species by its smaller size, 8–9 mm, while other species measure over 11 mm (Fig. 2A, B). Furthermore, it is easily identified by its swollen femur III, its curved tibia III, and the presence of a strong spine between the two spurs of tibia III (Fig. 2C), the size of which reaches or exceeds the thickness of the metabasitarsus III (Van der Zanden 1986; Al-Shahat and Hossni 2020). The female of *Lithurgus tibialis* is distinguished from all other *Lithurgus* species in the Palaearctic region by its size, 8–10 mm, while other species measure over 12 mm, associated with its white-coloured scopa (Van der Zanden 1986; Al-Shahat and Hossni 2020).

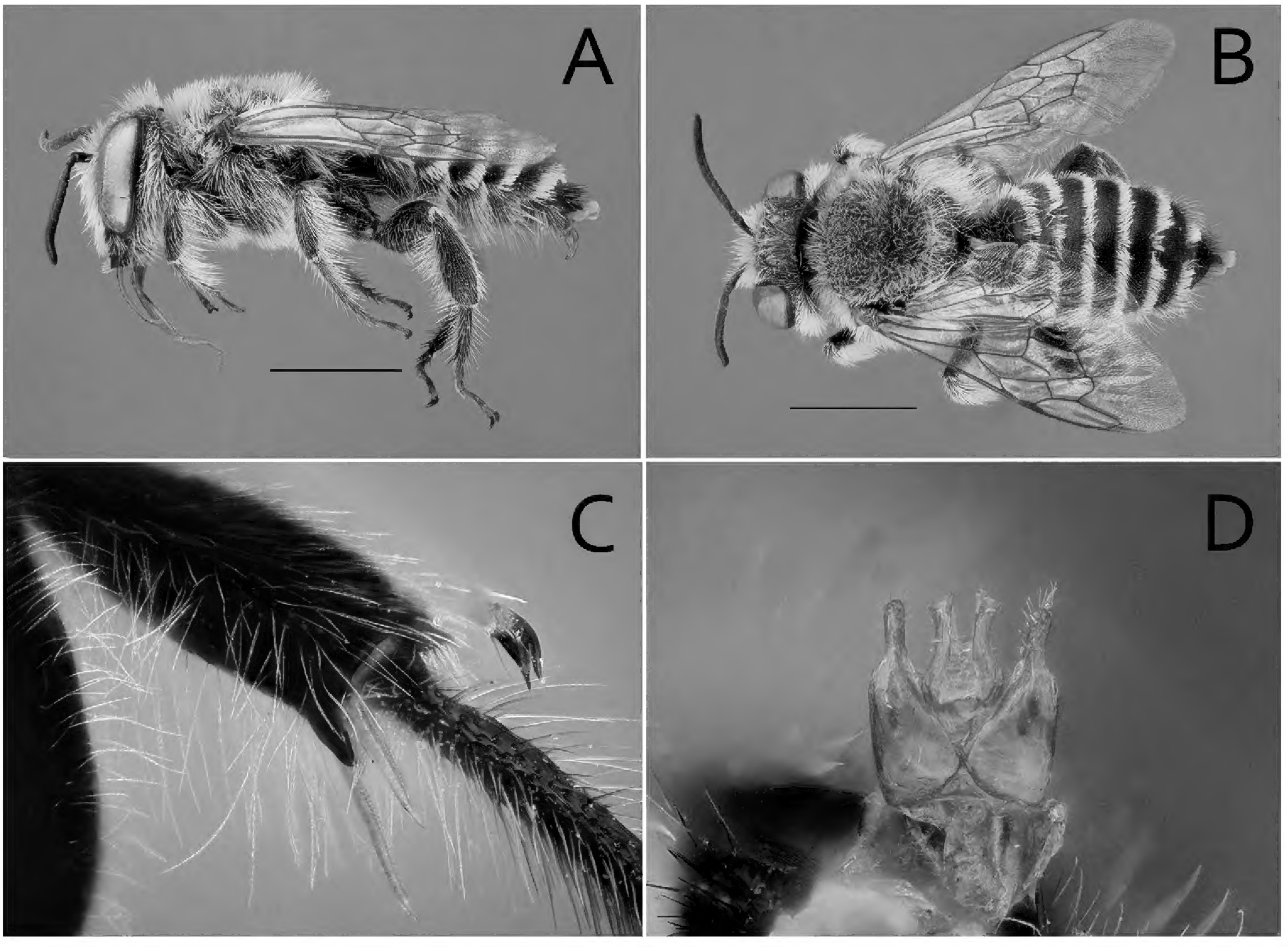

Figure 2. *Lithurgus tibialis*, male **A** lateral view **B** dorsal view **C** the spine in between metatibial spurs **D** genitalia.

Distribution. The distribution of *Lithurgus tibialis* spans from Southern Europe, Northern Africa, and the Middle East to Southern and Central Asia. In Europe, it has been reported in Cyprus, Greece, Italy, Portugal, Spain, Malta and Turkey (Van der Zanden 1986; Reverté et al. 2023). Its range extends into the Middle East, with records in Iran, Israel, Jordan, Syria, and the United Arab Emirates (Al-Shahat and Hossni 2020). This species also inhabits the Caucasus and Southern to Central Asia, as it has been documented in Afghanistan, Azerbaijan, India, Pakistan, Southern Russia, Tajikistan, Turkmenistan, and Uzbekistan (Fateryga et al. 2018; Maharramov et al. 2023). In Northern Africa, it is found in Algeria (Cros 1939) and Egypt (Al-Shahat and Hossni 2020). A previous citation for *Lithurgus tibialis* was given in a list of bee species pollinating a single crop in Morocco, without any further information (El Abdouni et al. 2022). The mentioned specimen was no longer available for this study.

Floral preferences. The females of *Lithurgus tibialis* appear to be oligolectic, primarily foraging on the Euphorbiaceae *Chrozophora tinctoria* (Christophe Praz, personal observation), while males may collect nectar from other species such as *Mentha* spp., on which the Moroccan specimens were collected.

Tetralonia aff. *lanzarotensis* Tkalců, 1993

Material examined. Morocco. 8♂, 1♀; Safi; 32.2587, -9.2386; 09 Apr. 2023; A. Sentil leg.; sweep net • 1♂; Safi; 32.2587, -9.2386; 15 Apr. 2023; A. Sentil leg.; sweep net • 3♂, 3♀; Safi; 32.2731, -9.2335; 21 Apr. 2023; A. Sentil leg.; sweep net • 3♂, 1♀; Safi; 32.3356, -9.2166; 23 Apr. 2023; A. Sentil leg.; sweep net • 15♂, 2♀; Safi; 32.2686, -9.2323; 25 Apr. 2023; A. Sentil leg.; sweep net • 1♀; Safi; 32.2625, -9.226617; 01 May 2023; A. Sentil leg.; sweep net • 2♂; Safi; 32.2587, -9.2386; 02 Jul. 2023; A. Sentil leg.; sweep net • 1♂, 6♀; Safi; 32.2735, -9.2334; 11 Jul. 2023; A. Sentil leg.; sweep net • 2♀; Safi; 32.2735, -9.2334; 15 Jul. 2023; A. Sentil leg.; sweep net.

Diagnosis. The species belongs to the *ruficornis*-group (Tkalců 1979) based on the metasomal hair pattern and structure, which comprises basal tomentum, and the marginal zones of T2–4 that largely exposed (Fig. 3B); the strongly branched scopal hairs (Fig. 3A); the lack of ventral mesosomal brush of unbranched thickened hairs of females; the shape of the medial longitudinal groove of S6, and the ventral tubercule of hind femur of males. Within the group, females of *Tetralonia lanzarotensis* can be diagnosed based on the short metasomal basal tomentum that does not reach the marginal zones of T3 and not (Lanzarote) or barely (Morocco) reach that of T4 medially; it differentiates from most other species, except *T. fulvescens* Giraud, by the black, immaculate face, and can be differentiated from that latter species by the lighter, ferruginous to reddish ventral side of flagellar segments 2–12 (Fig. 4A, B) (although some southern distributed specimens of *T. fulvescens* have lighter flagellar segments, and the diagnosability of this characteristic is not determined), and by the slightly smaller body size of about 9 mm (compared to mostly above 10 mm in *T. fulvescens*). The males are similar to females in their body size, 8.5–9 mm, short basal tomentum on T2–4 (Fig. 3D),

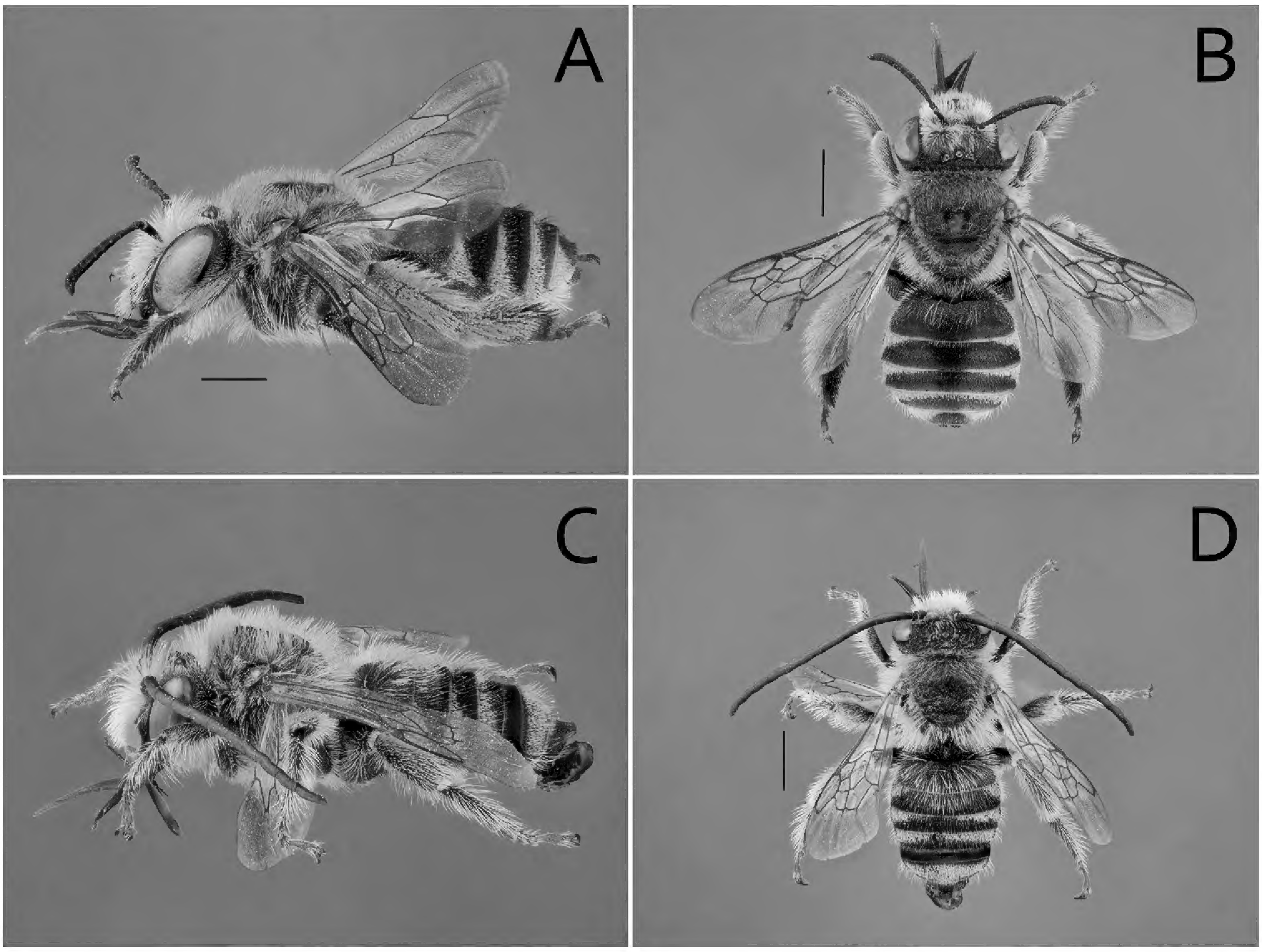

Figure 3. *Tetralonia* aff. *lanzarotensis*, female, from Morocco **A** lateral view **B** dorsal view. *Tetralonia* aff. *lanzarotensis*, male, from Morocco **C** lateral view **D** dorsal view.

and light flagellar segments ventrally; the ventral tubercule of hind femur is blunt and giving rise to dense, stiff sclerotised hairs. These characteristics, and to a lesser extent, also the widely emarginated lateral process of S7 (Fig. 4C), are most closely resembling *T. julliani* (Pérez), from which they can be easily differentiated by the elbowed gonostylus as seen in lateral view, with the apex produced medially, L-shaped as seen in dorsal view (compared to more gently curved and apically straight in *T. julliani* and in *T. fulvescens*). The genital complex of the male, which is usually diagnostic in the Eucerini, is nearly identical in specimens from the type locality in Lanzarote and in males from continental populations in Morocco (Fig. 4D). However, both the females and males clearly differ in the sculpture (and color) of the metasomal tergites (Fig. 3B, D), having sparser punctures apicomedially on the marginal zones and wider and translucent apical impunctate margins in specimens from Lanzarote as compared to those of the continent. The males from Lanzarote also have conspicuously shorter antennae. While such differences are generally considered sufficiently diagnostic at the species level, additional study that includes molecular evidence would be useful to determine species concepts with confidence.

Distribution. As far as it is known to us, the species has previously been recorded only from the island of Lanzarote in the Canary Islands (Reverté et al. 2023). It is first

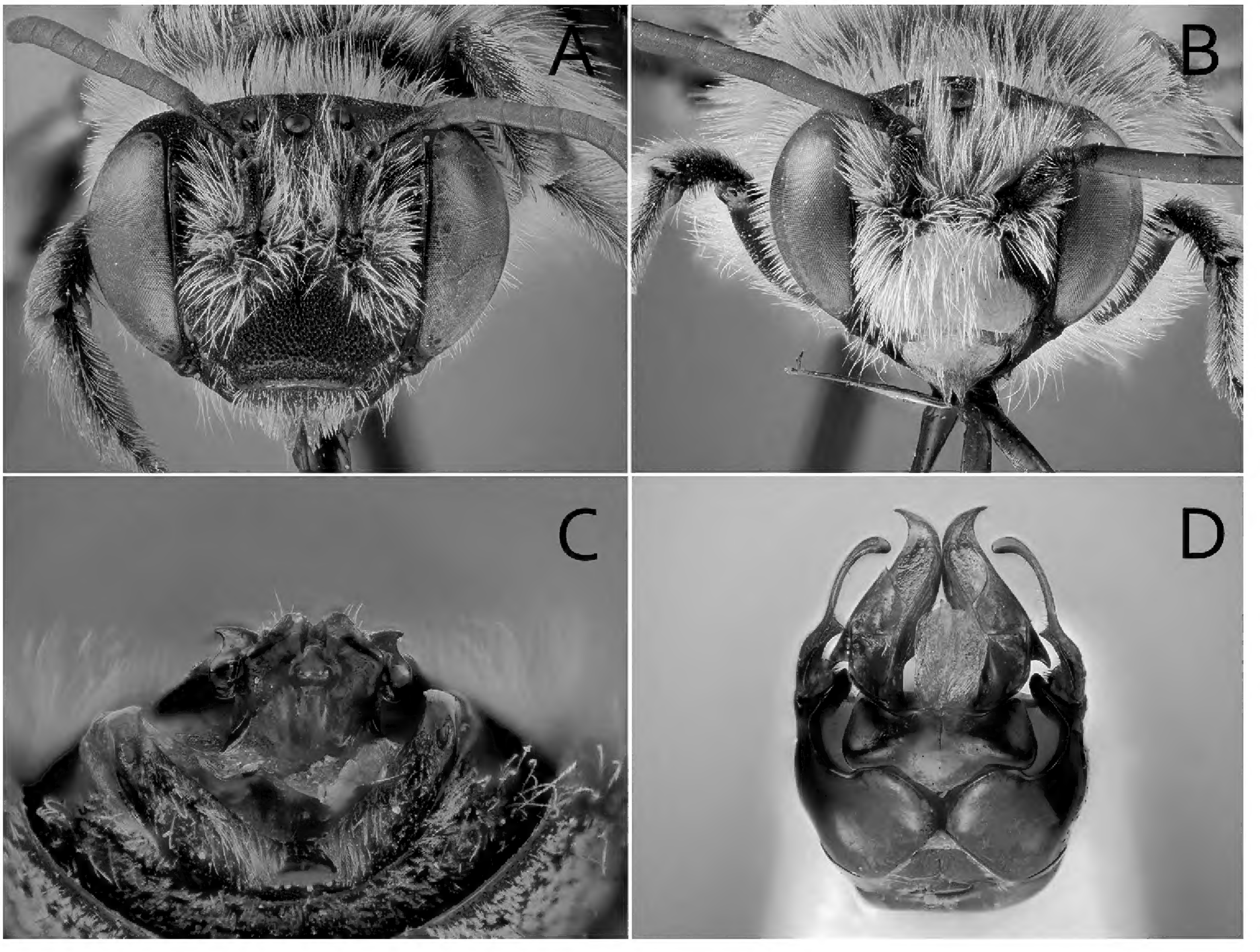

Figure 4. *Tetralonia* aff. *lanzarotensis*, female, from Morocco **A** frontal view. *Tetralonia* aff. *lanzarotensis*, male, from Morocco **B** frontal view **C** metasomal sterna 6 **D** genital capsule.

reported in this work from several localities in Morocco based on specimens from Safi and Tamri near Agadir on the Atlantic coast, and a single specimen examined from Ait Ibourk near Ouarzazate.

Floral preferences. Analyses of pollen removed from the scopa of ten female specimens from Safi, show that the species is associated exclusively with Asteraceae. More specifically eight females collected a pure sample of pollen of the subfamily *Asteroidea*, only one specimen collected a significant amount of pollen of *Carduoidea* (thistles), and another specimen collected a negligible amount of *Cichorioidea*.

Coelioxys ruficauda Lepeletier, 1841

Material examined. Morocco. 12♂; Safi; 32.2587, -9.2386; 09 Apr. 2023; A. Sentil leg.; sweep net • 1♂; Safi; 32.2587, -9.2386; 15 Apr. 2023; A. Sentil leg.; sweep net • 1♀; Safi; 32.2731, -9.2335; 21 Apr. 2023; A. Sentil leg.; sweep net • 1♂; Safi; 32.3356, -9.2166; 23 Apr. 2024; sweep net • 1♂; Safi; 32.2686, -9.2323; 25 Apr 2023; A. Sentil leg.; sweep net • 1♀; Safi; 32.2625, -9.2266; 30 Apr. 2023; A Sentil leg.; sweep net • 1♀; Safi; 32.2625, -9.2266; 01 May 2023; A. Sentil leg.; sweep net.

Diagnosis. The species belongs to the subgenus *Allocoelioxys*, which comprises usually smaller species with scale-like hair on the body (Fig. 5A–D). This species has snow-white hairs on the body and short last metasomal segments. Very often and especially in populations from North Africa, the bees display reddish pattern, especially on the last metasomal segments, parts of legs, flagellum and mandible. The portion of reddish colouration is smaller than in other related species, except *Coelioxys echinatus* (Warncke 1992). Both sexes have unbroken whitish apical bands on T1–T5, while the band on male T5 is wider than in the other species.

The male has unbroken whitish bands of scale-like hair on the metasoma (Fig. 5D) and the S4 is without emargination. The T2 has a transverse carina, which can differ this species from *C. afer*, in which this carina is absent (Fig. 5D). Medial teeth on T6 are reduced and the whole S6 is much more narrowed than in other related species (Fig. 6B). The female can be recognized by its slightly elongate last tergum and sternum of reddish colour (Fig. 6A). The apex of S6 is triangular-shaped and bears reddish hairs, and is considered typical for this species (Fig. 6A).

The last metasomal segments are much narrower than those of all related species and the distance between apical tooth-like processes on last tergum and sternum is very small, much smaller than in all other similar species (Fig. 6B).

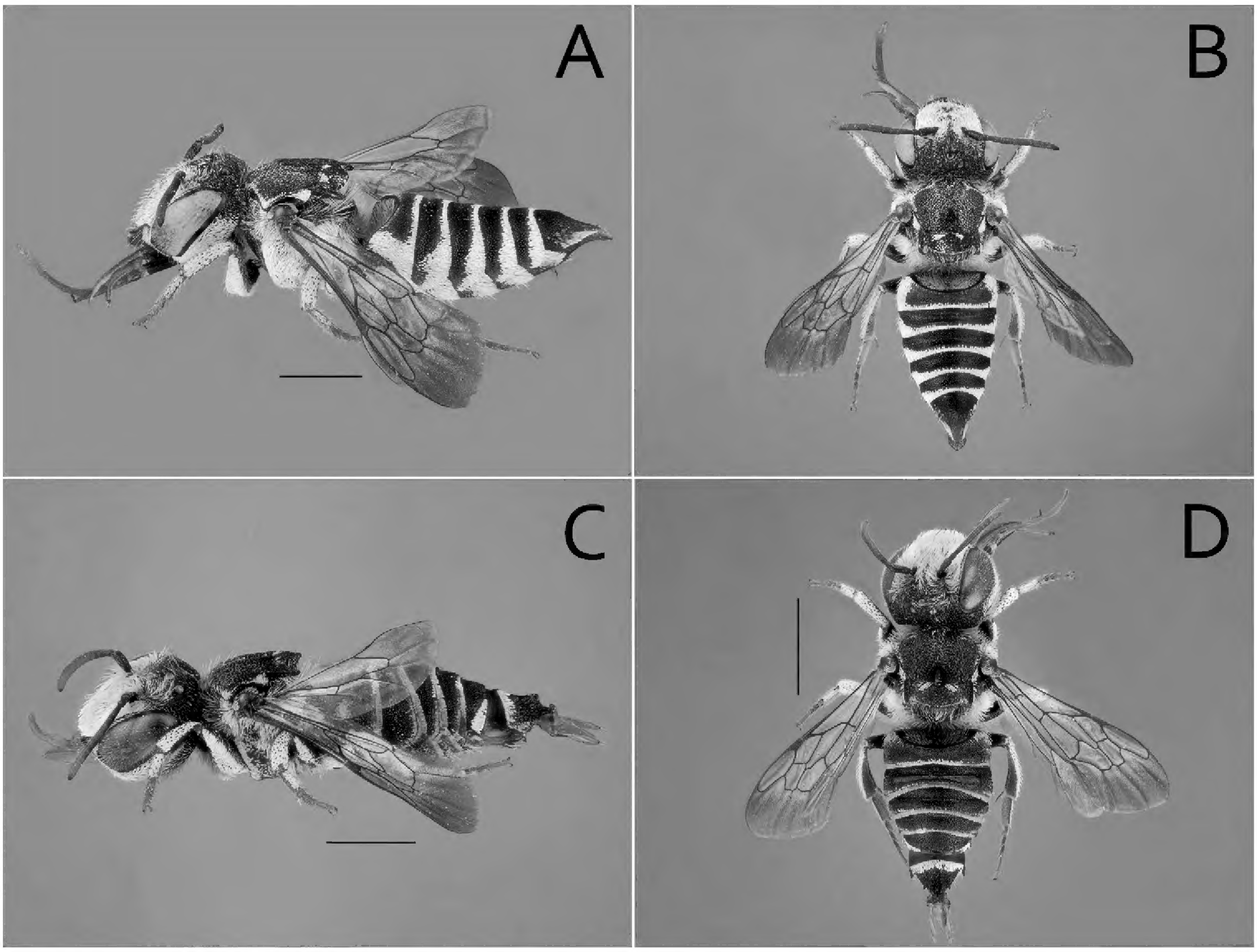

Figure 5. *Coelioxys ruficauda*, female **A** lateral view **B** dorsal view. *Coelioxys ruficauda*, male **C** lateral view **D** dorsal view.

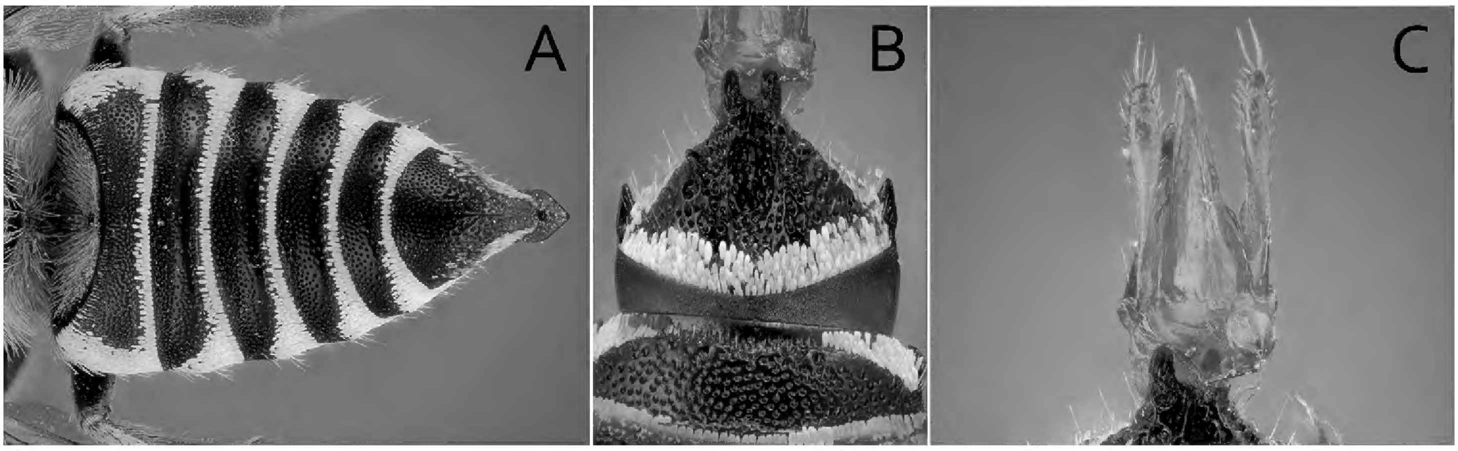

Figure 6. *Coelioxys ruficauda*, female **A** last metasomal terga, dorsal view. *Coelioxys ruficauda*, male **B** last metasomal terga, dorsal view **C** genitalia, dorsal view.

Distribution. The species is known from southern and Central Europe, Middle East and North Africa (Warncke 1992), with the northern distribution border going through the Czech Republic (Reverté et al. 2023). In Europe, most records are known from the South-West (South of France, Spain and Portugal) (Baldock et al. 2018). It occurs mainly in dry habitats with a high proportion of salt in the ground and it is everywhere considered to be a rare species.

Host. This species is a cuckoo bee and therefore does not collect pollen. *Megachile deceptoria* (P. Bogusch, personal observation) is its main host species in Central Europe. Both sexes feed on nectar of various plants, usually of the family Asteraceae (*e.g.*, genera *Centaurea*, *Cirsium*, and *Inula*).

Further information. Warncke (1992) found out that this species was for a long time recorded under the junior synonym *Coelioxys obtusa* Pérez, 1884.

Discussion

Despite the considerable works conducted over the last years in Morocco (Lhomme et al. 2020; Wood et al. 2020; Wood 2023a, Wood 2023b), significant knowledge gaps on bee diversity and ecology still persist. Opportunistic monitoring in a small urban area and a botanical garden, revealed three new species for Morocco, 28 new bee species for the region Marrakech Safi and a new species for science (*Anthophora ahlamae*, Rasmont and Wood (2024)). The three new records were expected, considering their occurrence in neighboring countries. This highlights the potential faunistic influence from Europe, Northern Africa, and regional endemism (Patiny and Michez 2007).

Our results highlight the extent to which the Moroccan bee fauna remains poorly documented. Research initiatives and national monitoring programs on bee diversity, distribution, behavior and ecology are lacking. The status and trends of Moroccan bee populations are entirely unknown. Further investigations and substantial taxonomic changes are needed for their taxonomy and classification. Without a consistent taxonomic framework and clearer insight into national bee diversity and distribution,

advanced research on the Moroccan bee fauna (e.g. population trends, national red list, factors of decline) may be hindered and future conservation actions may fail to support bees. Despite the high economic value of crop pollination and the crucial role bees play in ecosystem functioning (Klein et al. 2007; Ollerton et al. 2011; Sabbahi 2022), which have led to numerous inventories and research on bee conservation in agricultural and natural landscapes (Christmann et al. 2017, 2021; Hamroud et al. 2021; Sentil et al. 2021; Sentil et al. 2022a, Sentil et al. 2022b; Bencharki et al. 2022; El Abdouni et al. 2022), the bee fauna in urban areas remains largely unexplored.

Urban areas can also drive bee decline (Oke et al. 2021). Urbanization refers to the growth and the expansion of cities, which lead to the removal of natural habitats or the fragmentation of continuous habitats (Gu et al. 2021). It is generally considered to be one of the most important factors driving pollinator decline (IPBES 2019a, 2019b) and one of the most inhospitable environments for bees (Oke et al. 2021). However, some factors, such as floral resource availability, green spaces and undisturbed sites can offer favorable microhabitats for bees (Hall et al. 2017), at least for some functional groups of bees (Fauviau et al. 2022). In Safi, the tolerance of wild flowering plants in vacant lots and field borders, along with the presence of semi-natural habitats (e.g., in cemeteries), has led to the observation of more than one-tenth of the Moroccan bee species fauna, despite the low sampling effort. The importance of urban areas as a refuge for wild bee communities has been demonstrated in many publications; for instance, one-third of the bee fauna of France has been recorded in Lyon (Fortel et al. 2014) and half of the German bee species in Berlin (Saure 1996). Cities should promote pollinators for two reasons: (1) biodiversity protection and (2) pollination service provision. The expansion of urban areas worldwide is leading to significant losses in natural habitats (Wenzel et al. 2020). Thus, supporting bees that are losing their native habitats requires the incorporation of bee conservation plans in urban planning and agendas (Nilon et al. 2017). Moreover, cities with favorable bee habitats (e.g., cemeteries, roadside verges, parks), could act as refuges and corridors for bees (Fig. 7), and thus improve bee diversity in nearby simplified landscapes through spillover effect (Goulson et al. 2010). Additionally, bees ensure the pollination of native and ornamental plants, which in turn provide habitats and resources for other organisms, including insects, birds, and mammals. Also, high levels of biodiversity are required to boost urban ecosystem resilience in the face of climate change (Engström et al. 2020). Therefore, it is necessary to establish and maintain bee-friendly habitats in urban areas to promote and sustain diverse bee communities.

To date, no conservation strategies or initiatives have been developed to protect bees in Moroccan cities. The current knowledge of citizens about bees and the valuable services they provide is low and insufficient to catalyze the policy makers to implement conservation actions. These factors, combined with some management practices such as mowing, herbicide application and livestock grazing aggravate the pressures that bees are encountering in cities.

Nevertheless, bee conservation in Moroccan cities is still possible. A first step would be the transfer of knowledge on bees, and their ecological and economic

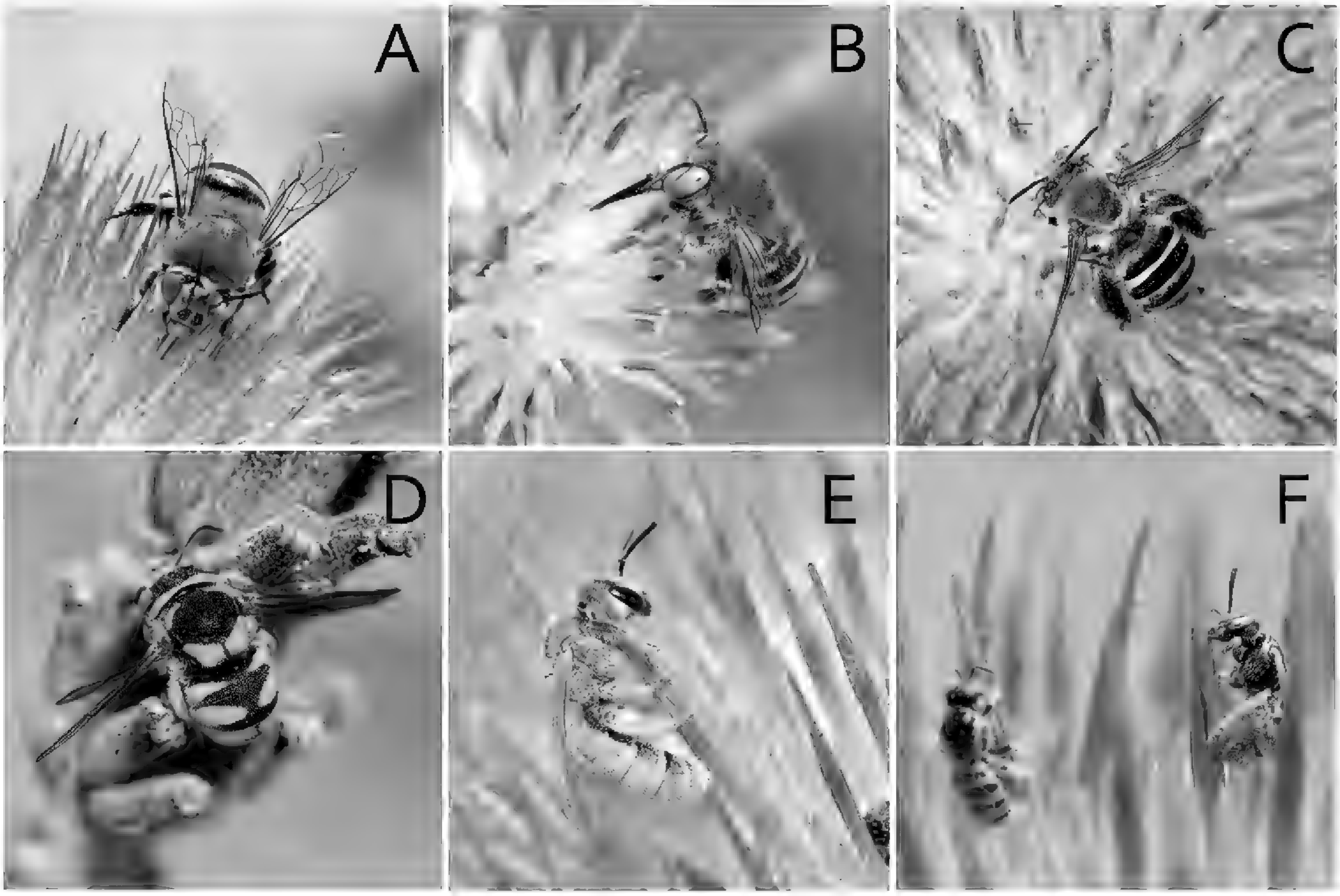

Figure 7. photos of some wild bee species observed during insect survey on wild flowering plants **A** *Amegilla quadrifaciata* **B** *Anthophora* sp. **C** *Eucera dentata* **D** *Anthidium strigatum* **E** *Seladonia* sp. **F** *Nomioides* sp.

importance to policy makers and urban planners. Second, adjust the urban management practices to promote bee-friendly environments, for instance: (i) delaying the mowing of roadside vegetation and/or reducing the mowing frequency (Chaudron et al. 2016; Wastian et al. 2016). Consider mowing the strip of vegetation immediately adjacent to roadsides, leaving the remainder of the row vegetation and the bee populations it supports intact. (ii) Prohibiting the use of herbicides in cities. For example, cemeteries provide suitable nesting sites and forage sources for bees (McCune et al. 2020; Macinnis et al. 2023). However, the urban cleaning service applies annually herbicides during spring to eliminate wild flowering plants. Alternatively, instead of eradicating all the wild plant fauna, we propose to at least preserve the existing wild flowering strips around cemeteries.

Conclusion

Despite the considerable efforts made to explore the Moroccan fauna, significant knowledge gaps persist regarding bee diversity and ecology. National monitoring programs and research initiatives on bee diversity, biogeography and ecology are imperatives for tailoring effective conservation actions. While urbanization poses threats to

bees, it can still provide suitable habitats that promote bee communities. Transferring knowledge to city planners and preventing harmful practices can mitigate pressures on urban bee populations and ensure their preservation.

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Supplementary material 1

List of bee species collected during the course of the study

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Data type: xlsx

Explanation note: The table summarizes the list of bee species collected during the course of the study. The bee species abundance (the number of bee individuals collected per genus) are indicated. The bee species newly recorded in the region Marrakech Safi are written in bold and highlighted in green.

Link: https://doi.org/10.3897/jhr.97.125408.suppl1